

CLAIMS

1. A gallium nitride compound semiconductor multilayer structure comprising a substrate, and an n-type layer, an active layer, and a p-type layer formed on the substrate, the active layer being sandwiched by the n-type layer and the p-type layer, and the active layer comprising a thick portion and a thin portion, wherein the active layer has a flat lower surface (on the substrate side) and an uneven upper surface so as to form the thick portion and the thin portion.

5 2. A gallium nitride compound semiconductor multilayer structure according to claim 1, wherein the active layer contains In.

10 3. A gallium nitride compound semiconductor multilayer structure according to claim 1, wherein the upper surface of the active layer is covered with a thin layer not containing In.

15 4. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 3, wherein the thick portion has a thickness of 15 Å to 50 Å.

20 5. A gallium nitride compound semiconductor multilayer structure according to claim 4, wherein the thick portion has a thickness of 15 Å to 30 Å.

25 6. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 5, wherein the thick portion has an arithmetic mean width, as measured in a cross-section of the multilayer structure, of 10 nm or more.

30 7. A gallium nitride compound semiconductor multilayer structure according to claim 6, wherein the thick portion has a width, as measured in a cross-section of the multilayer structure, of 100 nm or more.

35 8. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 7, wherein the thin portion has a thickness of 15 Å or less.

9. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 8, wherein the thin portion has an arithmetic mean width, as measured in a cross-section of the multilayer structure, of 100 nm or less.

5 10. A gallium nitride compound semiconductor multilayer structure according to claim 9, wherein the thin portion has a width, as measured in a cross-section of the multilayer structure, of 50 nm or less.

10 11. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 10, wherein the difference in thickness between the thick portion and the thin portion falls within a range of 10 Å to 30 Å.

15 12. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 11, wherein the thick portion has an area accounting for 30% or more the entire area of the active layer.

20 13. A gallium nitride compound semiconductor multilayer structure according to claim 12, wherein the thick portion has an area accounting for 50% or more the entire area of the active layer.

25 14. A gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 13, wherein the active layer is at least one well layer in a multiple quantum well structure.

30 15. A gallium nitride compound semiconductor multilayer structure according to claim 14, wherein the multiple quantum well structure is repeatedly stacked 3 to 10 times.

16. A gallium nitride compound semiconductor multilayer structure according to claim 15, wherein the multiple quantum well structure is repeatedly stacked 3 to 6 times.

35 17. A gallium nitride compound semiconductor multilayer structure according to any one of claims 14 to 16, wherein the multiple quantum well structure has a

barrier layer formed of a gallium nitride compound semiconductor selected from GaN, AlGaN, and InGaN which has an In content lower than that of the InGaN forming the active layer.

5 18. A gallium nitride compound semiconductor multilayer structure according to claim 17, wherein the barrier layer is formed of GaN.

10 19. A gallium nitride compound semiconductor multilayer structure according to claim 17 or 18, wherein the barrier layer has a thickness of 70 Å to 500 Å.

20. A gallium nitride compound semiconductor multilayer structure according to claim 19, wherein the barrier layer has a thickness of 160 Å or more.

15 21. A gallium nitride compound semiconductor light-emitting device, wherein the device has a negative electrode and a positive electrode, the negative electrode and the positive electrode being provided on the n-type layer and the p-type layer of a gallium nitride compound semiconductor multilayer structure according to any one of claims 1 to 20, respectively.

22. A gallium nitride compound semiconductor light-emitting device according to claim 21, which has a flip-chip-type device structure.

25 23. A gallium nitride compound semiconductor light-emitting device according to claim 22, wherein the positive electrode has a reflection-type structure.

30 24. A method for producing a gallium nitride compound semiconductor multilayer structure including a substrate, and an n-type layer, an active layer, and a p-type layer formed on the substrate, the active layer being sandwiched by the n-type layer and the p-type layer and comprising a thick portion and a thin portion, wherein the method comprises a step of forming the active layer, which step includes a step of growing a gallium nitride compound semiconductor and a step of decomposing or sublimating a portion of the gallium nitride compound semiconductor.

25. A method for producing a gallium nitride compound semiconductor multilayer structure according to claim 24, wherein the active layer contains In.

5 26. A method for producing a gallium nitride compound semiconductor multilayer structure according to claim 25, wherein the active layer is grown by continuously supplying a nitrogen source and a Group III metal source containing In and Ga and, subsequently, a thin layer not containing In is formed on a surface of 10 the active layer by stopping the feeding of the In metal source.

15 27. A method for producing a gallium nitride compound semiconductor multilayer structure according to any one of claims 24 to 26, wherein the step of growing is performed at a substrate temperature of T1 and the step of decomposing or sublimating is performed at a substrate temperature of T2, wherein T1 and T2 satisfy the relationship: $T1 \leq T2$.

20 28. A method for producing a gallium nitride compound semiconductor multilayer structure according to claim 27, wherein T1 falls within a range of 650 to 900°C.

25 29. A method for producing a gallium nitride compound semiconductor multilayer structure according to claim 28, wherein T2 falls within a range of 700 to 1,000°C.

30 30. A method for producing a gallium nitride compound semiconductor multilayer structure according to any one of claims 24 to 29, wherein the step of growing is performed in an atmosphere containing a nitrogen source and a Group III metal source and the step of decomposing or sublimating is performed in an atmosphere containing a nitrogen source but not containing a Group III metal source.

35 31. A method for producing a gallium nitride compound semiconductor multilayer structure according to claim 30, wherein the step of decomposing or sublimating

is performed while the substrate temperature T1 is elevated to T2.

32. A method for producing a gallium nitride compound semiconductor multilayer structure according to 5 claim 31, wherein the substrate temperature T1 is elevated to T2 at a temperature elevation rate of 1°C/min to 100°C/min.

33. A method for producing a gallium nitride compound semiconductor multilayer structure according to 10 claim 32, wherein the temperature elevation rate is 5°C/min to 50°C/min.

34. A method for producing a gallium nitride compound semiconductor multilayer structure according to any one of claims 31 to 33, wherein the substrate 15 temperature T1 is elevated to T2 over 30 seconds to 10 minutes.

35. A method for producing a gallium nitride compound semiconductor multilayer structure according to 20 claim 34, wherein the substrate temperature T1 is elevated to T2 over one minute to five minutes.

36. A method for producing a gallium nitride compound semiconductor multilayer structure according to any one of claims 27 to 35, wherein the active layer is 25 at least one well layer in a multiple quantum well structure, and at least one barrier layer in the multiple quantum well structure is grown at T2, followed by lowering the substrate temperature to T3 at which further growth is performed.

37. A method for producing a gallium nitride compound semiconductor multilayer structure according to 30 claim 36, wherein T3 is equal to T1.